A LANCHESTER - BASED MODEL FOR INVESTIGATING ALTERNATIVE AMBUSHER DEPLOYMENT TACTICS IN SMALL UNIT AMBUSHES

Seri Riddhiroj

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A LANCHESTER - BASED MODEL FOR INVESTIGATING ALTERNATIVE AMBUSHER DEPLOYMENT TACTICS IN SMALL UNIT AMBUSHES

by

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A Lanchester - Based Model for Investigating Alternative Ambusher Deployment Tactics in Small Unit Ambushes

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I. SUMMARY

The purpose of the study reported in this thesis was to identify and relate the major variables of ambush combat engagements in such a way that different ambusher deployments could be studied. When a small ambusher plans an attack on an enemy with strength about four times larger, decisions must be made concerning the location of the ambusher and the relative position of the enemy when the ambusher initiates fire.

Following work by Deitchman to model the ambush situation, a set of Lanchester type equations portraying small force guerrilla engagements were developed by Schaffer. These equations are employed here with claymores, T48, used as the supporting weapons to investigate five ambusher tactical deployments. To analyze various tactical combinations and situations, parameter values were taken from research by other authors, recorded military statistics, and personal combat knowledge. Force sizes were updated by the computer program every five-tenth of a minute of the battle. Success in battle was considered dependent upon infliction of casualties on the opposing force.

The results suggest that a very small ambusher force gains additional advantage by attacking at the front or the rear of the larger ambushed force when the ambushed force is just ready to enter a curve, or attacking the rear of the

convoy just after the end of the convoy passes the curve, than attacking at the side of the convoy.

II. INTRODUCTION

An ambush is a surprise attack from a concealed position on an enemy force. The key word is "surprise." Without surprise, there is no ambush. An ambush is offensive in nature. It is usually a brief encounter and does not require the capture and holding of ground. Ambush may be used in front of and behind the enemy, against both regular and insurgent forces. A series of successful ambushes will make the enemy apprehensive and cautious in movement. Continued success will finally inflict a virtual paralysis on the enemy [8].

The ambush was a popular and successful tactic in the Vietnam War [9], [10], [11]. Of course, the results of engagements are varied and depend upon a number of factors such as the length of the engagement, the positions of the ambushers, and the quantity and quality of intelligence information.

It may be possible to achieve the aim of an ambush by using a very small number of men and covering the selected killing ground with anti-personnel mines such as the claymores or other controlled explosive devices. Once the weapons have been emplaced the ambush can be sprung by one or two men. This layout is particularly effective against targets whose characteristics are well-known.

In this thesis we shall present a deterministic mathematical model of ambush which will take into account possible deployments of the ambusher force. This model will be based on Shaffer's extension to Lanchester's theories of combat and will be used to investigate the effectiveness of alternative ambusher deployment schemes.

Specifically, the type of action which will be studied is an ambush attack where the mission of the attacking force is to disturb and destroy the enemy. It is a brief encounter and does not require the capture and holding of ground. The ambush force will have ample time to select a deployment scheme and prepare its positions. When it initiates fire, it will have planned only a short period of time for the engagement and then withdraw before the arrival of a reaction force or the total recovery of the ambush force. The defensive, ambushed force, has the problem of how to get off the killing ground and effectively engage ambusher force.

The following chapter presents the background and the development of the Lanchester theories. The modification of the Lanchester equations to the ambush model will be discussed in Chapter IV. In Chapter V, we'll examine consequences of various deployment schemes for ambushers. The final chapter presents conclusion and recommendation for further study.

III. A MATHEMATICAL MODEL OF AMBUSH

The development of a mathematical model of ambushes will begin with the basic Lanchester equations of combat. Modification of the Lanchester equations suggested bu Deitchman to model the ambush situation will be discussed. A generalization of Deitchman's model proposed by Shaffer will be used to model the ambush situation.

F. W. Lanchester (1868-1946) was an English engineer. He developed his mathematical formulation for combat between two conflicting forces in an attempt to quantitatively justify Von Clausewitz's Principle of Concentration [7]. Lanchester's law considers two types of fighting. In the case where the opposing sides are not visible to each other, each man is assumed to fire into the area that he believes the opposing force occupies. This results in an attrition rate proportional to the number of men firing and the number of men occupying the area into which men are firing, and vice versa. If x and y are force sizes in time and both sides are using this area firing mode, the attrition rates for the two forces are

$$\frac{dx}{dt} = -axy \tag{1}$$

and

$$\frac{dy}{dt} = -bxy \tag{2}$$

where t is time since the beginning of the battle and a and b are called the attrition coefficients for Y and X respectively

The constant b depends upon such things as X's rate of fire and the lethality of his weapon, together with the degree to which Y is protected against area fire.

When (1) is divided by (2) we obtain

$$b\,dx = a\,dy. \tag{3}$$

We may integrate both sides of (3) over the time interval (0,t) to obtain

$$b(x_0 - x(t)) = a(y_0 - y(t)), \tag{4}$$

where x_0, y_0 are the initial forces of both sides, and $x(t)$, $y(t)$ are the forces at time t. Equation (4) is called Lanchester Linear Law. It suggests that if one uses area fire against an enemy, there is no advantage to be gained by concentrating one's force [7].

Another case occurs where each unit may take any enemy unit under fire and once a unit destroys an enemy unit, it may shift fire to another enemy unit. In this aimed fire case the attrition rates for the two forces are

$$\frac{dx}{dt} = -ay \tag{5}$$

and

$$\frac{dy}{dt} = -bx\ . \tag{6}$$

Dividing (5) by (6) and integrating yields the result

$$b(x_0^2 - x^2(t)) = a(y_0^2 - y^2(t)), \tag{7}$$

which is the Lanchester Square Law.

Deitchman has proposed a mixed linear-square law case for ambushes in which the ambusher force fires from concealed

positions with the ambushed force in his full view. The ambushes force, in defending itself, fires at the area it thinks the ambusher force occupies. The attrition rates of the ambushed force of size x, and the attrition of the ambusher force of size y are,

$$\frac{dx}{dt} = - Ay$$

$$\frac{dy}{dt} = - Byx ,$$

where t is the time since the ambush began and A and B are the ambushed and ambusher force's attrition coefficients, respectively. These differential equations yield

$$2A[y_0 - y(t)] = B[x_0^2 - x^2(t)],$$

where y_0 and x_o are the initial ambusher and ambushed force sizes respectively. The simultaneous differential equations can be solved numerically, making possible the calculation of the force size of the two sides at any time during the ambush if the initial force sizes and attrition coefficients are known.

The attrition coefficient of the ambusher force, (By) is taken to be the rate at which single rifleman in the ambushed force kills the ambushers. Here,

$$B = r_x \frac{A_e}{A_y} ,$$

where r_x = the rate of fire of each of the ambushed force's weapons,

A_e = the area of target which would produce a casualty, and

A_y = the total area which the targets occupy.

The ambushed force's attrition coefficient A is the product of the rate of fire r_y of the ambusher force's weapons and the single-shot kill probability of the ambusher force's weapon in aimed fire, P_y, or

$$A = r_y P_y .$$

These attrition coefficients have not been allowed to vary with time, implying that ambushed force remains in the full view of the ambusher force throughout the engagement and that the ambushed force does not improve its knowledge of the location of the ambusher force.

Marvin B. Shaffer developed a set of Lanchester type equations modeling small-force guerrilla engagements that are typical of the early stages of insurgency [4]. These equations include the effects of supporting weapons and the discipline, or morale of the troops involved. The attrition rate of the ambushed force of size x, in his model, is

$$\frac{dx}{dt} = -(1 - b_x)k_y(t)y - C_x\left(\frac{y}{x} - 1\right)^2$$

$$-(1 - b_x)\sum_i E_i(t,x)W_i(t) \qquad (8)$$

where $\sum_i E_i(t,x)W_i(t)$ reflects the support weapons of the ambusher force, y and x are the sizes of the ambusher force

and the ambushed force respectively, and $k_y(t)$ is the ambusher small-arms weapon efficiency coefficient. Here,

$$k_y(t) = \frac{r_y A_T(t) P_{h,k}}{2\pi\sigma_y^2} , \tag{9}$$

where r_y is the rate of fire of the ambusher force, $P_{h,k}$ is the conditional probability of killing given a hit, and σ_y is a radial dispersion of a single round fired by ambusher. If $A_T(t)$ is the area of a target through which the ambusher round will pass, then the probability that a single ambusher round hits the target is

$$\frac{A_T(t)}{2\pi\sigma_y^2} .$$

The change of the target area of a rifleman in the ambushed force is represented by

$$A_T(t) = \frac{A_T(\infty)}{1 - e^{-\alpha t - \beta}} , \tag{10}$$

where $A_T(\infty)$ is the minimum final presented area of an individual in steady state. Typical values of $A_T(\infty)$ for prone troops are 0.1 sq.ft. against rifle fire, and 0.5 sq.ft. against high explosive. In the denominater of (10), t is the time since the ambush began, α determines the speed at which the ambusher can approach the level of his maximum cover, and β determines the presented area of the individual at the instant the ambush begins. Typical values for α and β are 6.2 per minute and 0.1, which would imply that the

target achieves approximately 95% of eventual cover within 0.5 minutes.

Return to (8), b_x is a constant associated with troops discipline [4]. A coefficient reflecting "desertions" associated with being outnumbered is $C_x(t)$, for the ambusher, and the term $-C_x(t)(\frac{y}{x} - 1)^2$ is taken to reflect the ambushed force's rate of withdrawal. The attrition rate contribution produced by the support weapons of the ambusher force is given by,

$$\sum_i E_i(t,x)W_i(t)$$

where E_i is the weapon efficiencies of the ambusher's i types supporting weapons over time, and $W_i(t)$ reflects the supporting weapon strength of type i over time.

In Schaffer's model the ambusher force attrition rate, dy/dt, is proportional to the product of the weapon's efficiency coefficient for the ambushed force, $k_x(y,T)$, and the number of riflemen in the ambushed force who are firing, x. It is also proportional to the product of a withdrawal coefficient, $C_y(t)$, and the difference between the ambusher force ratio and unity, squared, and we have

$$\frac{dy}{dt} = -k_x(y,t)x - C_y(t)(\frac{x}{y} - 1)^2 - \sum_j E_j(t,y)W_j(t). \qquad (11)$$

The small-arms weapons coefficient $k_x(y,t)$ is explicitly time dependent, since there is a gradual transition from area

fire to aimed fire. A reasonable representation of $k_x(y,t)$ which simulates this transition is

$$k_x(y,t) = k''(1 - e^{-\gamma t}) + k'ye^{-\gamma t} \tag{12}$$

where

$$k' = r_x\left(\frac{A_e}{A_y}\right)P_{h,k} \tag{13}$$

and

$$k'' = r_x\left(\frac{A_e}{2\pi\sigma_y^2}\right)P_{h,k} \; . \tag{14}$$

When t = 0, the coefficient takes the appropriate form for area fire k'y, and when t is very large the coefficient takes the form for aimed fire, k''. The constant γ in equation (12) reflects the rate at which the ambushed force can change from area to aimed fire. A value of 0.102 for γ represents an ability to achieve 90% of the aimed fire condition in 23.5 minutes [7].

The term $C_y(t)(\frac{x}{y} - 1)^2$ in equation (11) reflects the ambusher force's rate of withdrawal from the ambush site. The withdrawal coefficient, $C_y(t)$, is interpreted by Schaffer as a step function which is dependent on both time and the ambushee - ambusher force ratio. It is defined as

$$C_y(t) = |C_y|[\,H(t-t_0)H(\tfrac{x}{y} - 1)] \tag{15}$$

where H is the unit step function, t_0 is the time required for discipline of an ambusher to deteriorate to the point when he may desert, t is time, and C_y reflects the training

and motivation of the ambushers. Thus $C_y(t)$ is a positive quantity when $t_j > t_0$ and $\frac{x}{y} > 1$, and is zero otherwise.

In (11), the supporting weapons term, $\sum_j E_j(t,y)W_j(t)$ is essentially of the same form as before.

In the following chapter, Schaffer's ambush model will be modified as necessary to reflect the ambush situations we wish to examine.

IV. MODIFICATIONS TO THE AMBUSH MODEL

In this chapter we shall suggest modifications to the Schaffer ambush model to reflect both deployment tactics on the part of the ambusher force, and ambusher use of claymores to set off the ambush. First, five different possible deployment configurations will be presented. Then, after discussing the tactical use of claymores, the Schaffer model will be modified to reflect the effect of a claymore firing to initiate an ambush. This will permit preparations for a numerical comparison of ambusher effectiveness using various tactical deployment schemes.

A. SCENARIO AND ALTERNATIVE DEPLOYMENT SCHEMES

The class of ambushes we shall examine involves a daylight attack against a convoy at a 90° curve in a road. The attack will begin with a claymore firing. In selecting the killing ground and deploying the ambushing force, the ambusher commander might consider five alternatives as follows:

1. Attack the front of the convoy as it is just ready to enter the curve, with support from six claymores, three emplaced along each side of the road. We will call this a Type 1 ambush, and a typical scenario is shown in Figure 1.

2. Attack the rear of the convoy just after the end of convoy passes the curve, also with support from three claymores emplaced along each side of the road. This Type 2 ambush is illustrated in Figure 2.

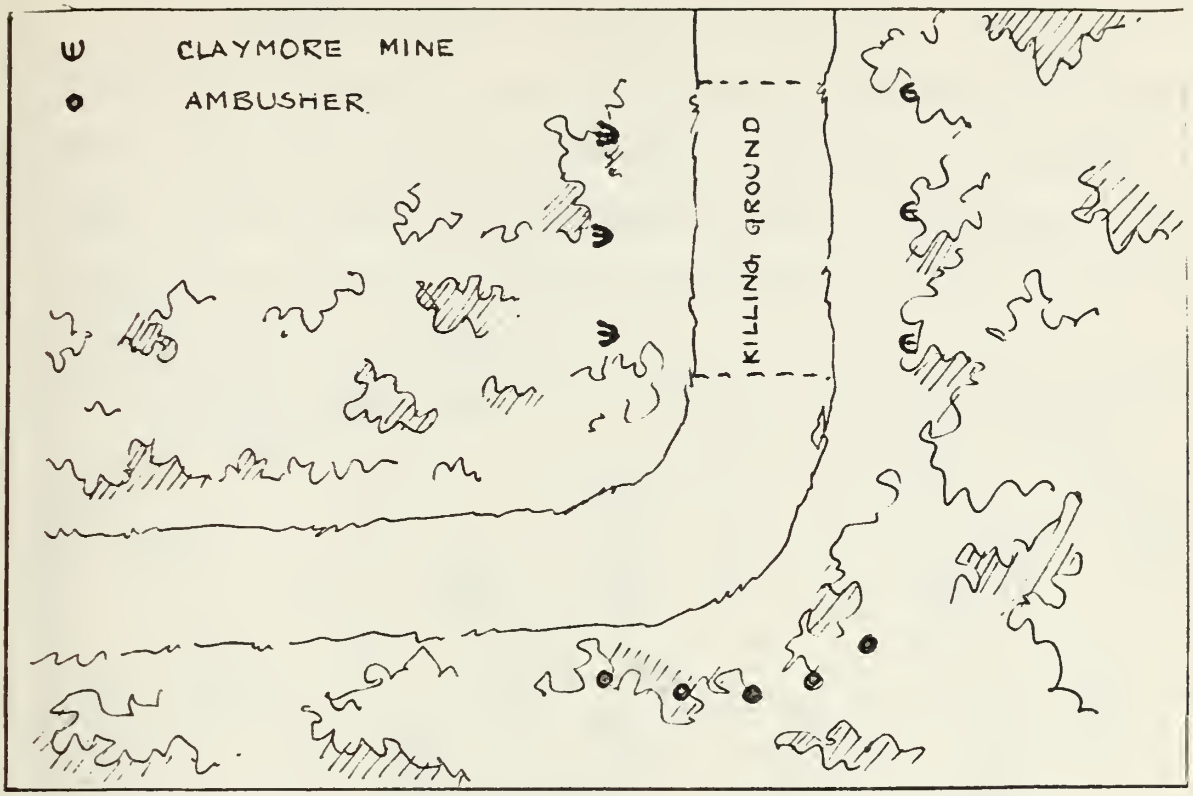

Figure 1. Typical Scenario for a Type 1 Ambush.

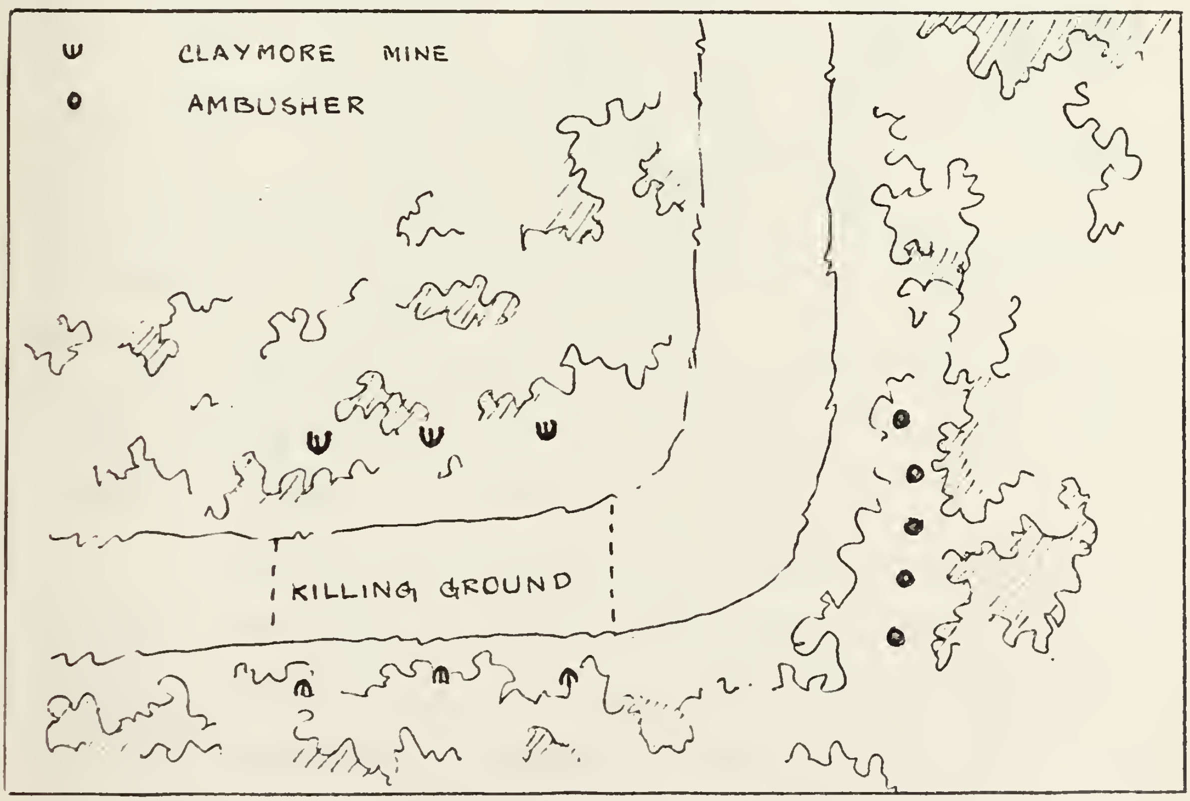

Figure 2. Typical Scenario for a Type 2 Ambush.

3. Attack from the outside of the curve, just as the middle of the column passes the curve, also with three claymores along each side of the road. This will be called a Type 3 ambush and clearly requires that the ambusher force lie in safe positions during the claymore firing. The scenario is shown in Figure 3.

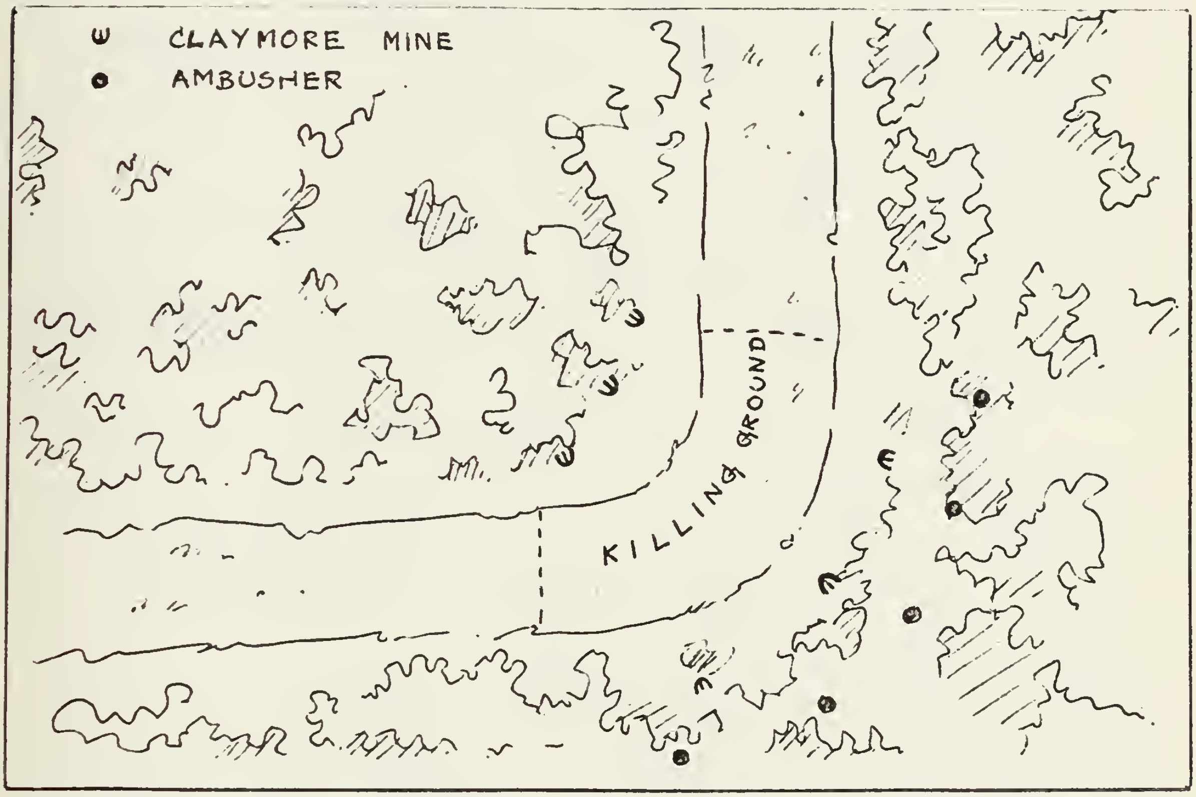

Figure 3. Typical Scenario for a Type 3 Ambush.

4. Attack in a manner similar to the type 3 ambush, but with ambushed force located inside the curve. This Type 4 ambush is shown in Figure 4.

5. Attack either side of the column or convoy before or after entering the curve of the road with six claymores, three on each side of the road. This type 5 deployment is one that would also be used if there were no curve in the road, and is shown in Figure 5.

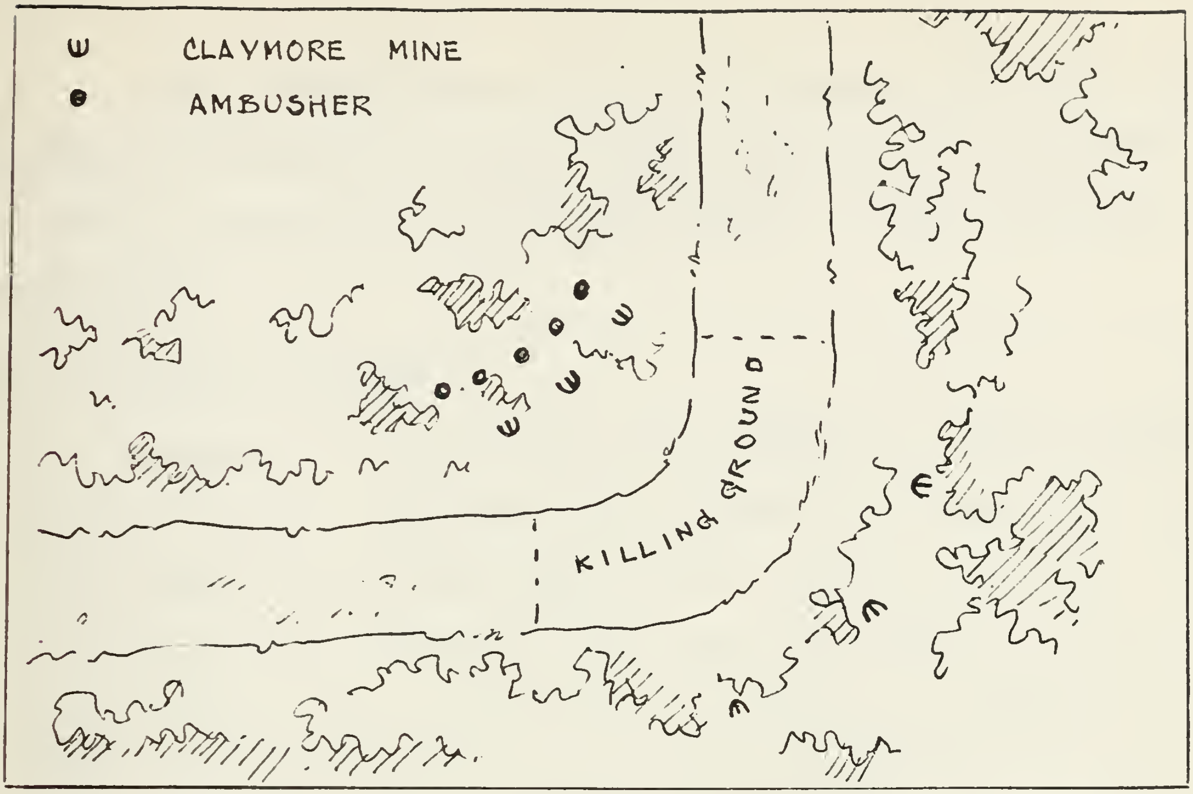

Figure 4. Typical Scenario for a Type 4 Ambush.

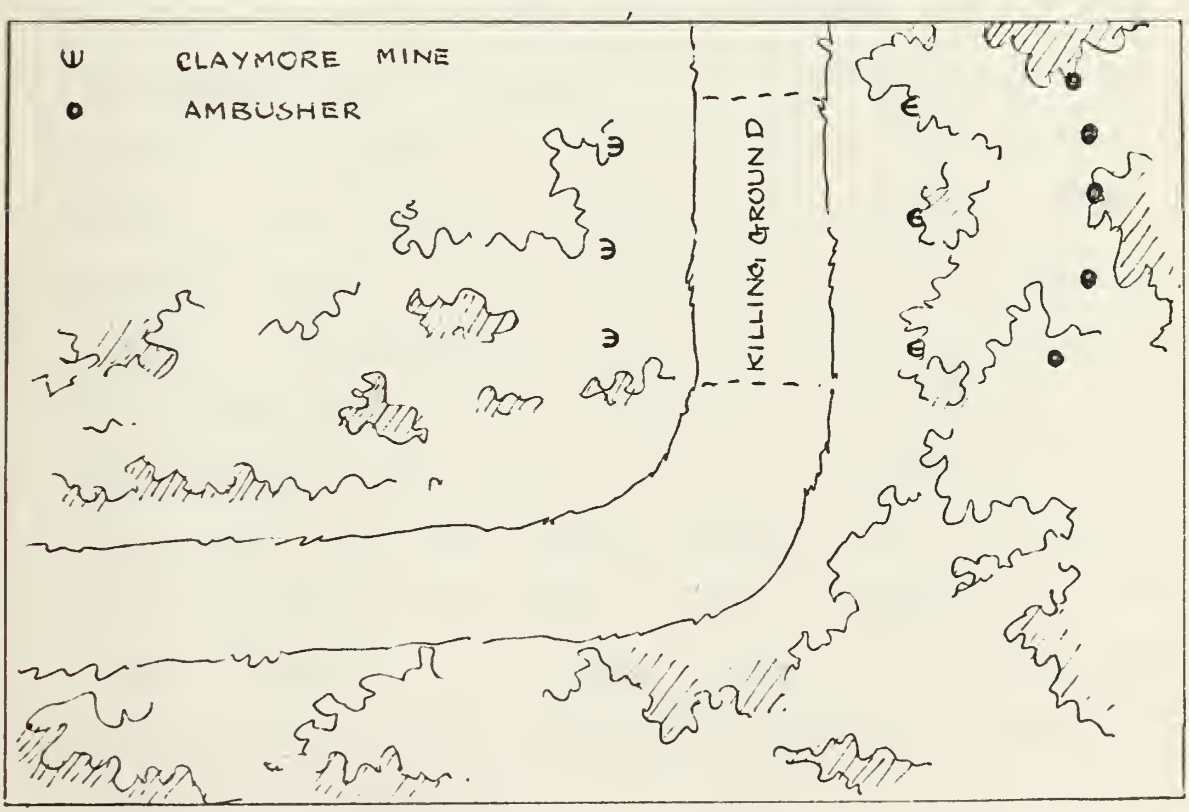

Figure 5. Typical Scenario for a Type 5 Ambush.

After a discussion of the use of claymores we will suggest how parameter values for the attrition rate equations may be selected to reflect the variety in these deployment schemes.

B. USE OF CLAYMORES

Claymores T48 are used as the ambusher's support weapon in this study. The controlled claymores are emplaced along both sides of the road approximately 100 feet from the center of the road and 80 feet apart, and aimed to the center of the road. In practice, the number of claymores used will depend on the size of the killing ground and the size of the ambushed force. The claymores will be located so that they cover the entire killing ground. It has been recommended that the length of the electrical leads must be longer than 50 feet [1]. Two men, one on each side of the road, will be assigned to control the claymores, When the ambushed force is in the killing ground or the high-value targets of the force are in the center of the killing ground, the claymores on one side of the road will be fired. This is immediately followed by firing the claymores on the other side. The time interval between the two claymores firing should be negligible. Then the ambusher riflemen begin firing at the surviving targets. They are assumed to continue firing until the end of the battle or when the ambusher force withdraws.

The lethality pattern of a T48 claymores, the probability of incapacitation as a function of the location of a person

relative to a detonated T48 claymores under simulated combat conditions has been estimated, and is shown in Appendix B.

C. ATTRITION RATE EQUATIONS

The ambusher force of size y is divided into two groups, a group of two men is assumed to control the claymores, and second group of y-2 men assigned to attack the ambushed force. We will assume that the two men who control the claymores are well concealed and not vulnerable to fire from the ambushed force. It is also assumed that there are no support weapons for the ambushed force, so $\sum_j E_j(t,y)W_j(t)$ can be set at zero. The ambushers are assumed to make a deliberate decision to commence a gradual withdrawal after a specific period of time, thus $C(t) > 0$. Then from equation (1), the ambusher attrition can be expressed as

$$\frac{d(y-2)}{dt} = -k_x(y-2,t)x - C_y(t)\left(\frac{x}{y-2} - 1\right)^2. \quad (16)$$

Since it is assumed that no desertions or surrenders take place in the ambushed force, the coefficients b_x and C_x can be set at zero. The claymores used by the ambusher are fired only once, at the beginning of the engagement. This is immediately followed by fire from the riflemen of the ambusher force. Since the claymores are fired just before continuous time-dependent attrition begins, the term $\sum_j E_j(t,y)W_j(t)$ can be set at zero. The initial strength of ambushed force, x_0, will be reduced to $x_0(1 - \bar{P}_k)$, where $\bar{P}_k$

is the average kill probability (lethality) from the burst of the six claymores.

The estimation of a value for $\bar{P}_k$ is as follows. It is assumed that all the units of the ambushed force are uniformly distributed over the killing ground, and claymore reliability is 1. The claymores are emplaced 100 feet from the center of the road which is, as a killing zone, 25 feet wide. Three claymores are emplaced on each side of the road, eighty feet apart. This configuration allows effective coverage and safety to the ambusher force. Using the lethality data in Appendix B and allowing for overlapping target coverage, the average may be estimated to be $\bar{P}_k$ = 0.518. (In the case that the targets are concealed in the vehicles, the probability might be reduced to, say, 0.35.)

The expected number of men in the ambushed force that are killed by claymores is $x_0\bar{P}_k$, and thus attrition after claymore firing will be in accordance with

$$\frac{d(x - x_0\bar{P}_k)}{dt} = -k_y(t)(y - 2). \tag{17}$$

The ambusher force attrition rate in equation (16) becomes

$$\frac{d(y - 2)}{dt} = -k_x(y-2,t)(x-x_0\bar{P}_k) - C_y(t)\left\{\frac{(x - x_0\bar{P}_k - 1)}{y - 2}\right\}^2 \tag{18}$$

These differential equations provide a model of the ambush situation permitting numerical computation of force sizes at various stage of the ambush. In the next section we shall discuss parameter estimation for rifle fire for each of the five alternative deployments.

D. PARAMETER ESTIMATES FOR THE ATTRITION RATE EQUATIONS

For the Type 1 and Type 2 deployment schemes, the number of the riflemen in the ambushed force to fire at the ambusher is limited by the width of the road. In this model we shall assume that at most, seven riflemen can fire at the ambusher force under these conditions, and that casualties will be replaced by the survivors behind.

For parameters in equation (9), (10), (12), (17) and (18) Burnell [3] suggested that these following values are appropriate to the ambush model for estimating $k_y(t)$:

$$A_T(\infty) = 1.68 \text{ ft}^2$$

$$\alpha = 0.572 \text{ per minute}$$

$$\beta = 0.4$$

and $$\sigma_y = 10 \text{ miles.}$$

These permit computation of $k_y(t)$ in (17).

For computing aimed and area fire attrition coefficients for fire on the ambushers, Burnell suggests

$$\gamma = 0.516 \text{ per minute}$$

$$\sigma_x = 10 \text{ miles,}$$

and from other sources we have

$$A_e = 0.54 \text{ ft}^2 \text{ , [6]}$$

$$P_{h,k} = 0.80 \qquad \text{[2].}$$

A maximum rate of fire is 40 rounds per minute, which is the sustained rate of fire of the M-14 rifle [5]. Other studies have suggested that the combat rate of fire could be estimated by multiplying the theoretical rate of fire by 0.5 [3],

thus

$$r_x = 20 \text{ rounds per minute,}$$

and

$$r_y = 20 \text{ rounds per minute.}$$

The final parameter estimate comes from Burnell, who suggests $C_y = 1.0$ [3].

With these parameter values, the ambushed force effectiveness using aimed fire, k", can be obtained by solving equation (11) We assume that the area A_y which is occupied by ambushers and fired into by the ambushed force is about 800 square yards for Type 1 and Type 2 ambushes. This yields $k' = 0.0012$ as the attrition coefficient for the ambushed force using area fire.

It should be noted that our treatment of ambush Type 1 and 2 is such that, in the modeling sense, they are indistinguishable. Accordingly, we shall treat them as a single type of ambush.

For Ambush Types 3, 4 and 5 all of the ambushed force survivors can fire by using area fire and then aimed fire with the same parameters as in Type 1 and Type 2 ambushes. What is different is that the area A_y occupied by the ambusher will vary with the type of attack. For Ambush Type 3 this area is the largest, and for this case we will assume $A_y = 1{,}200$ square yards which yields $k' = 0.0008$. For Ambush Type 4, A_y is the smallest, say 730 square yards, yielding $k' = 0.00132$. In a Type 5 ambush, ambushes will occupy an

area larger than in the Type 1 and 2 ambushes, but not as large as in the Type 3 ambush where they occupying the outside of the curve. We will assume an area A_y = 1,000 square yards here, or k' = 0.00096. This value is the same as Schaffer had suggested [4].

Using these values, the simultaneous differential equations developed in Chapter IV may be solved on a digital computer. A computer program was written to solve the differential equations using a Runge-Kutta fourth order numerical integration technique and will be discussed in the next chapter.

V. NUMERICAL SOLUTIONS TO THE AMBUSH MODEL

A purpose of this thesis is to compare within a limited scenario the effectiveness of alternative deployment tactics for the ambushing force. To do this, a computer program was designed to furnish numerical solutions to the model, thus providing results of simulated engagements fought under different ambusher deployment schemes. This chapter discusses the results of this computer work.

A. THE COMPUTER PROGRAM

The computer program designed to calculate the outputs of the model uses the FORTRAN IV language and was run on an IBM 360 computer. At the end of every 0.5 minutes of ambush time, the program calculates the casualties for both sides and the current ratio of force strength. It then uses these as inputs for the next time increment. The program runs until either the ambushing force is reduced to the two men who control the claymores, or the ambushed force is anihilated. The computer program is given in Appendix A.

B. MODEL RESULTS

Using the numerical values for model parameters discussed in the preceeding chapter, the two differential equations comprising the model were solved numerically for each of the ambusher deployment schemes. Results are tabulated in Appendix C and shown graphically in Figures 6, 7, 8, 9, and 10.

Figure 6 shows force sizes over time for ambush Types 1 and 2. Of the various deployment schemes considered, the Type 1 and 2 ambushes were the most successful, yielding a clearcut victory for the ambushers without withdrawal after 3.5 minutes. In other deployment schemes, seven minutes were required for the ambushed force to be defeated.

Results were almost identical for the Type 3 ambush, where ambushers were located outside the curve in the road, the Type 5 ambush, where ambusher were located beside the road, and the Type 4 ambush where ambushers were inside the curve. Force sizes over time for these three deployment schemes are shown in Figures 7, 8, and 9. The model used an area of 29,000 square yards to hold the ambushers in the Type 4 ambush, while the Type 3 and Type 5 ambushes allowed the ambushers areas of 48,000 and 40,000 square yards, respectively. The Type 4 ambush hardly represents "packing" targets (240 square yards of area for each rifleman, initially) and computer results show negligible differences between it and more spacious deployments.

In Figure 10, ambushed-ambusher force ratios are plotted at 0.5 minute intervals during the ambush for the various deployment schemes. Here, the advantages of the Type 1 and Type 2 schemes (where, at most, seven men in the ambushed force could return fire) are clear. It may also be seen that if the ambushers withdraw at 2.5 minutes, all the various deployment schemes will yield rather similar results.

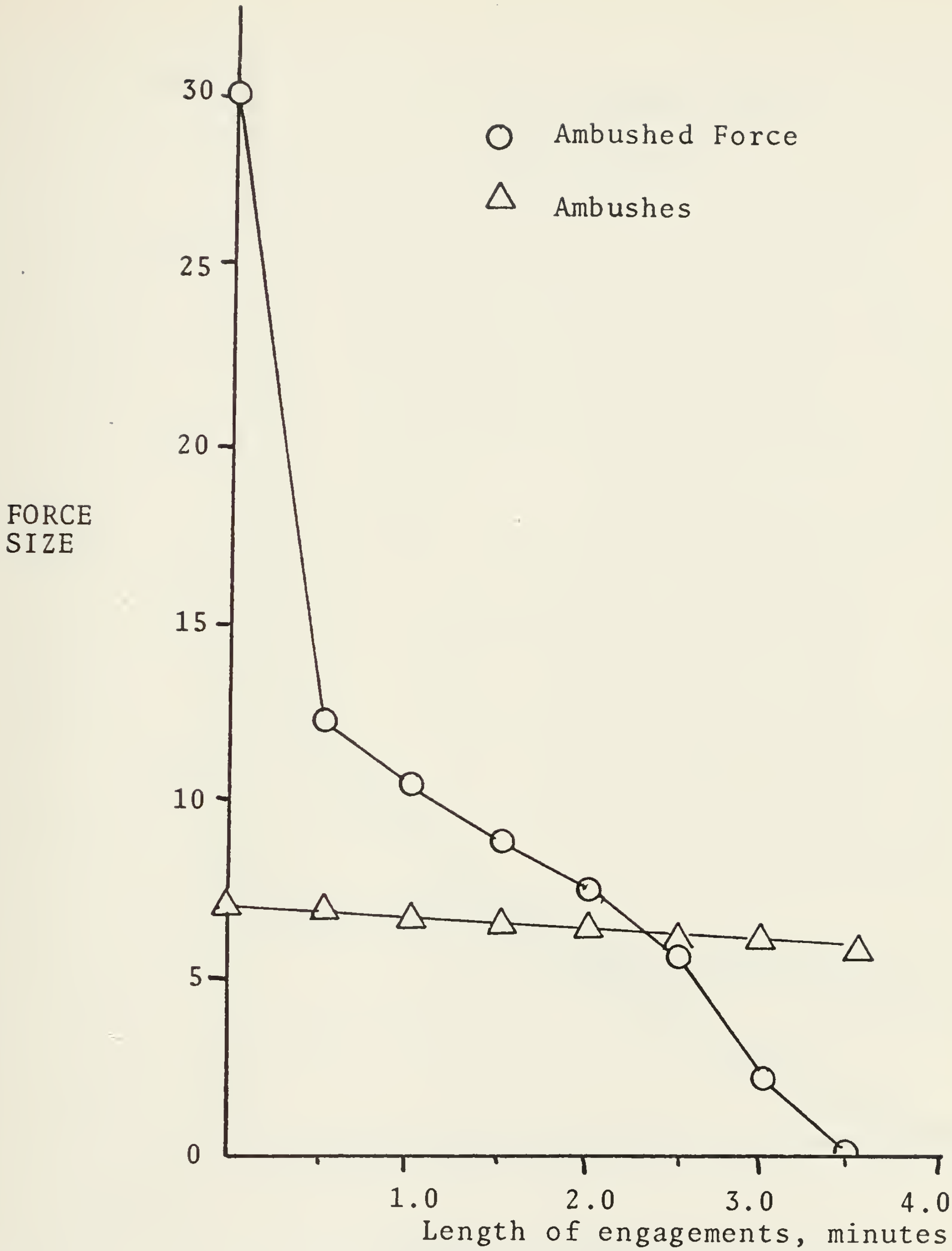

Figure 6. Force Sizes over time for Type 1 and Type 2 Ambushes.

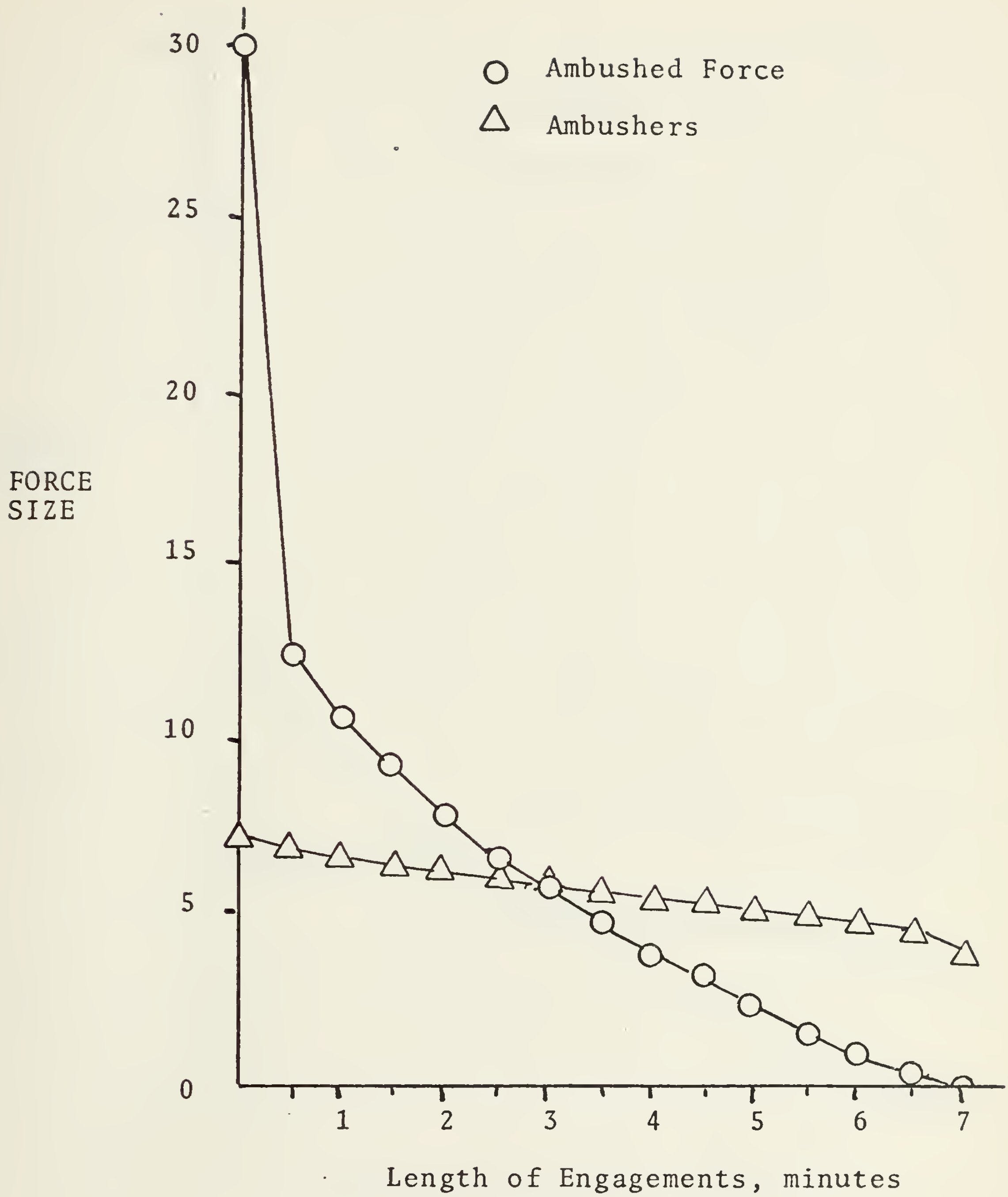

Figure 7. Force Sizes Over Time For Type 3 Ambushes.

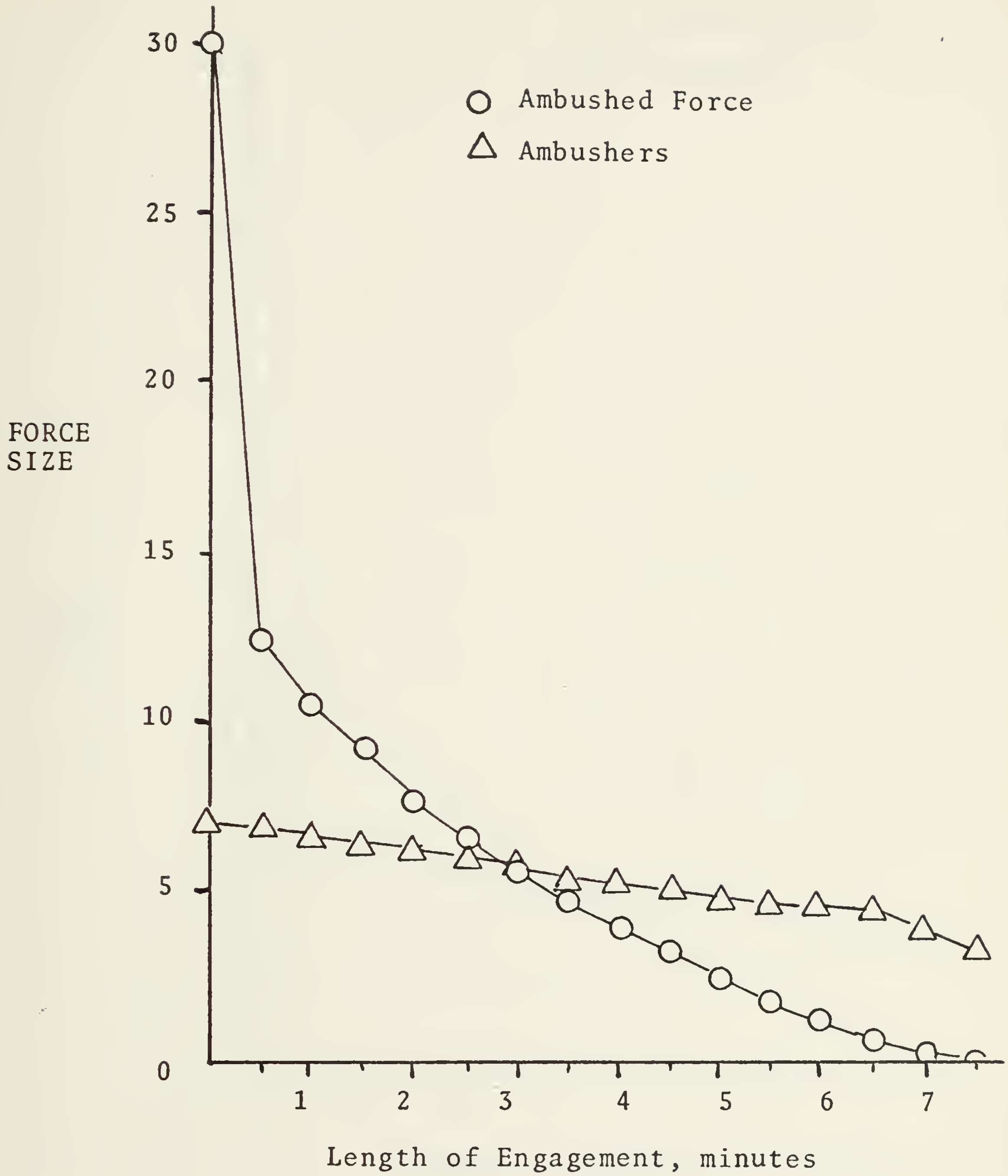

Figure 8. Force Sizes Over Time for Type 4 Ambushes.

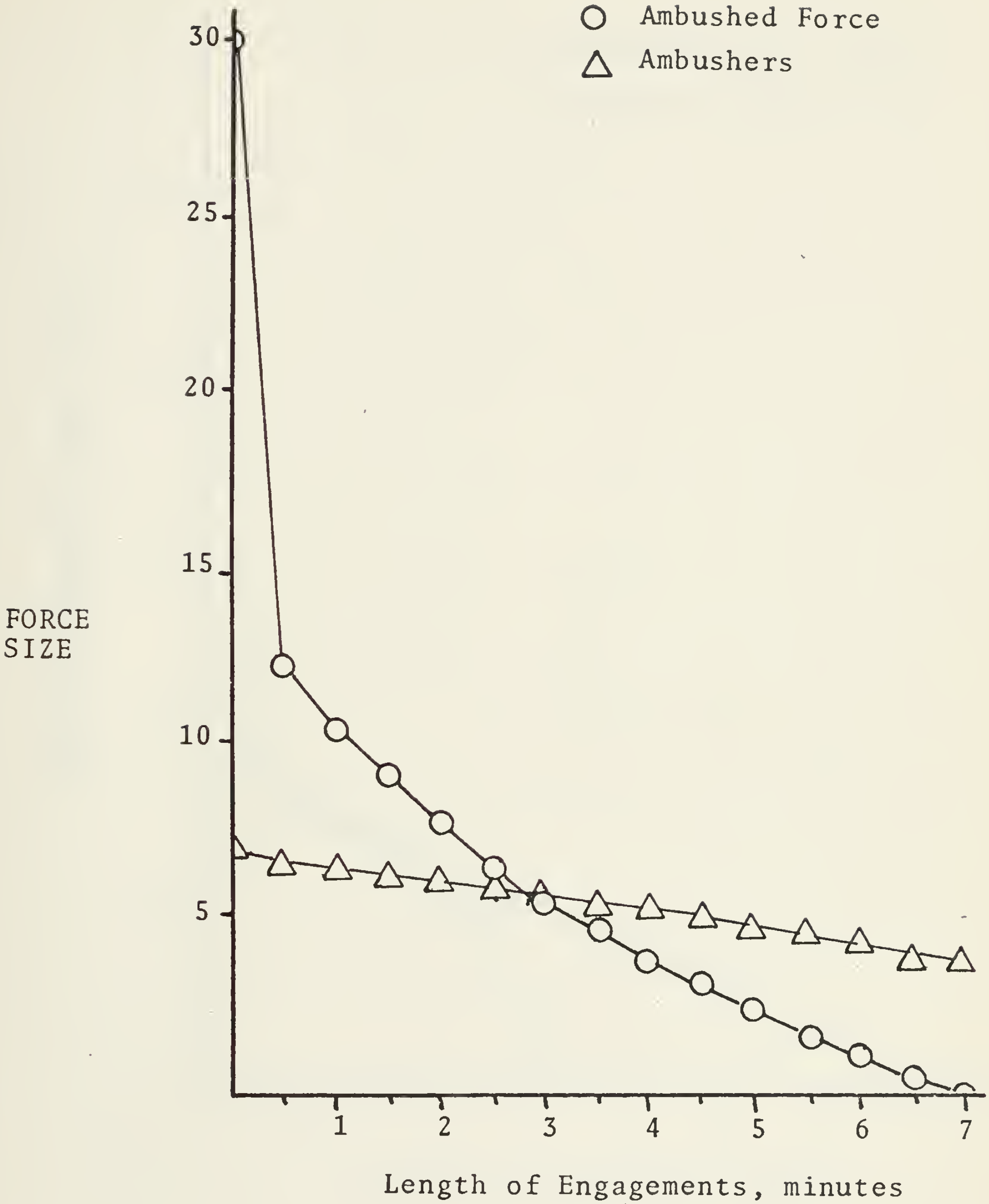

Figure 9. Force Sizes Over Time for Type 5 Ambushes.

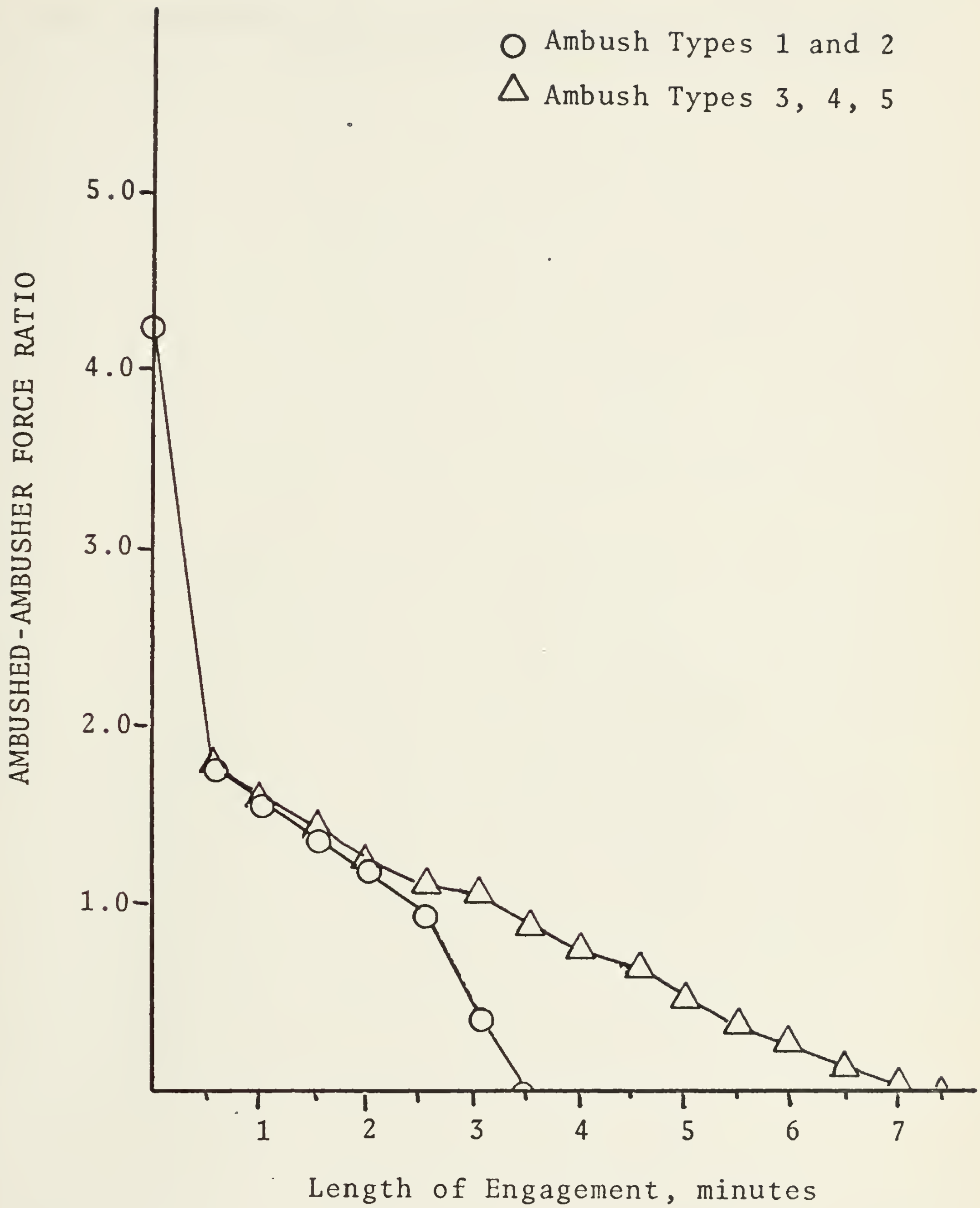

Figure 10. Ambushed-Ambusher Force Ratios for Various Deployment Schemes and Engagement Lengths.

In the next chapter, we will give conclusions from the study and recommendations for further work in this area.

VI. CONCLUSIONS AND EXTENSIONS

In this chapter general conclusions are made concerning the results from the computer and suggestions are given for extensions. A model has been presented in this thesis to predict the casualties for both sides in an ambush attack on an ambushed force. Because the model is based on Lanchester's theories of combat, the assumptions associated with those theories must be made in the development of this model.

These extensions to Lanchester's theories of combat assume that fire is uniformly distributed over an area or group of targets. Generally, when targets are visible, the unit attempts to fire at all targets (assuming they are all equally important). But, in area fire, fire will usually be directed at the most likely enemy locations rather than over the whole target area. Nevertheless the model developed in this thesis has the supposition that area fire is uniform over the entire area. It is also assumed that the supply of ammunition is not a factor in the problem.

The essential results of the study in this thesis are that there appear to be modest advantages from deploying the ambushing force at a curve in the road so that the ambushers are located so as to fire along the road, either at the front of an oncoming column or the reat of a departing column. This presupposes the presence of the claymores covering the

entire killing zone. In this study using documented claymore lethalities and relatively soft targets, most of the ambushee attrition occurred during the initial claymore firing.

While these results seem quite reasonable, there are many areas of the model which could be further studied. One is the concept supporting weapons. The use of the claymores in this thesis presumes perfect intelligence about size of the enemy force, and they are all fired at the beginning of the engagement. A worthwhile effort would be to use the model with a different type of support weapon such as artillery. Another shortcoming of the model is that it is designed for only single shot weapons. Since automatic weapons are very much a part of modern warfare, altering the model to handle correlated rounds from other than single shot weapons would be most beneficial.

This paper has provided a first analysis of the effects of ambusher deployment on ambush outcomes. There are clearly many other studies which could be done regarding force deployment in ambushes. It is hoped that this thesis will be useful both to those who are concerned with the problems of ambushes and to those who propose to undertake further studies in this area.

APPENDIX A: COMPUTER PROGRAM FOR THE AMBUSH MODEL

```
//RIDH1257 JOB (0449,0399FT,ROX1),'RIDH',TIME=(01,30)
// EXEC FORTCLGP,REGION.GO=100K
//FORT.SYSIN  DD  *
C
C
C
C        THIS COMPUTER PROGRAM CONSISTS OF TWO PARTS,ONE TO DETERMINE
C        THE OUTCOME OF AN AMBUSH,WHEN ATTACK TO THE FRONT AND REAR OF
C        THE COLUMN OF AMBUSHED FORCE,THE OTHER TO DETERMINE THE OUTCOME
C        OF THE AMBUSH WHEN ATTACK AT THE SIDE OF THE AMBUSHED FORCE.THE
C        MAIN PART OF THE PROGRAM READS IN THE DATA AND CONTROLS WHICH
C        SUBROUTINE IS CALLED.
C
      COMMON/COM1/TDEL1,TMAX,MRED,RED,PBAR/COM2/APHK,ZETA,DELTA/COM3/AK1
     1,AK2,GAMMA,ROAD/COM4/CN
C
C
C
C        RMW   = INITIAL AMBUSHED FORCE SIZE
C        BN1   = INITIAL AMBUSHER FORCE SIZE
C        ROAD  = THE WIDTH OF THE ROAD
C        TMAX  = TIME AT WHICH THE AMBUSHER FORCE MAY BEGIN TO WITHDRAW
C                IF OUT NUMBERED
C        RB    = RATE OF FIRE OF THE AMBUSHER FORCE
C        AT    = STEADY-STATE VALUE OF THE AMBUSHED FORCE-COVER
C        DELTA = ACONSTANT WHICH DETERMINES THE RATE AT WHICH THE
C                AMBUSHED FORCE CAN ATTAIN COVER
C        ZETA  = A CONSTANT WHICH DETERMINES THE PRESENTED AREA OF THE
C                INDIVIDUAL IN THE AMBUSHED FORCE.
C        GAMMA = A CONSTANT WHICH DETERMINES THE RATE AT WHICH THE
```

```
C                 AMBUSHED FORCE SHIFTS FROM AREA TO AIMED FIRE.
C          ZIGMA = SING-SHOT RADIAL DISPERSION OF FIRE.
C          AK1   = THE AMBUSHED FORCE WEAPONS EFFICIENCY COEFFICIENT FOR
C                  AREA FIRE.
C          AK2   = THE AMBUSHED FORCE WEAPONS EFFICIENCY COEFFICIENT FOR
C                  AIMED FIRE.
C          CN    = A CONSTANT WHICH DETERMINES THE RATE AT WHICH THE
C                  AMBUSHER WITHDRAW.
C          TDEL1 = TIME INCREMENT USED IN RUNGE-KUTTA-GILL INTEGRATION
C                  ROUTINE.
C          PHK   = SINGLE-HIT KILL PROBABILITY.
C
C
C
C
      I=1
 1000 READ (5,1) RMW,BN1,ROAD
      READ(5,11) TMAX,RB,AT,DELTA,ZETA,GAMMA,ZIGMA
      READ(5,11) AK1,AK2,CN,TDEL1,PHK
    1 FORMAT (6X,3(F5.1,2X))
      MRED    = RMW
      NBLU    = BN1
      WRITE(6,3) I,NBLU,MRED,TMAX,ROAD
    3 FORMAT('1',41X,'AMBUSH TYPE',2X,I2,//,28X,'INITIAL AMBUSHER FORCE.
     3............= ',I3,//,28X,'INITIAL AMBUSHED FORCE..............= ',
     4I3,//,28X,'AMBUSHERS MAX. TIME OF ENGAGEMENT      =',F5.1,//,28X,'
     5THE WIDTH OF THE ROAD                   =',F5.1)
   11 FORMAT(12(F10.6))
      A       = RB*AT/(2.0*3.1416*ZIGMA**2.0)
      APHK    = A*PHK
      WRITE (6,4)
    4 FORMAT ( //,27X,' TIME(MIN) ',3X,' AMBUSHERS FORCE',3X,' AMBUSHED
     1 FORCE ',3X,' AMBUSHED-AMBUSHER FORCE RATIO ')
      RED = ROAD/3.0

      AVERAGE KILL PROBABILITY UNDER THE AREA OF CLAYMORES COVERAGE
```

```
      PBAR=0.518
      IF (I.GT.2) GO TO 1004
      CALL RKUTTA(RMW,BN1,X,Y)
      GO TO 504
 1004 CALL MKUTTA(RMW,BN1,X,Y)
  504 I=I+1
      IF (I.GT.5) GO TO 1003
      GO TO 1000
 1003 STOP
      END


      SUBROUTINE RKUTTA (RMWB,BN1B,XR,YR)


      COMMON/COM1/TDEL1,TMAX,MRED,RED,PBAR
      T=0.0
      X2=RMWB
C
C     THE NUMBER OF AMBUSHED FORCE IS REDUED BY RMWA*P,RESULTED FROM
C     THE CLAYMORES
C
      RMWB=RMWB-RMWB*PBAR
C
C     TWO MEN WHO CONTROL THE CLAYMORES ARE NOT IN THE RANGE OF RIFLE.
      BNX=BN1B-2
  104 IF (RMWB.LT.RED) GO TO 30
      RMY=RED
      GO TO 31
   30 RMY=RMWB
C
C     RUNGE-KUTTA METHOD BEGINS.
C
   31 IF (T-0.0) 112,112,103
  103 IF (T-TMAX) 106,105,105
  105 IF (RMWB-BN1B) 106,106,107
  106 F1=TDEL1*TKNT(BNX,T)
      G1=TDEL1*DNT(RMY,BNX,T)
```

```
      F2=TDEL1*TKNT(BNX+G1/2.0,T+TDEL1/2.0)
      G2=TDEL1*DNT(RMY+F1/2.0,BNX+G1/2.0,T+TDEL1/2.0)
      F3=TDEL1*TKNT(BNX+G2/2.0,T+TDEL1/2.0)
      G3=TDEL1*DNT(RMY+F2/2.0,BNX+G2/2.0,T+TDEL1/2.0)
      F4=TDEL1*TKNT(BNX+G3,T+TDEL1)
      G4=TDEL1*DNT(RMY+F3,BNX+G3,T+TDEL1)
      GO TO 108
  107 F1=TDEL1*TKNT(BNX,T)
      G1=TDEL1*DNTC(RMY,BN1B,T)
      F2=TDEL1*TKNT(BNX+G1/2.0,T+TDEL1/2.0)
      G2=TDEL1*DNTC(RMY+F1/2.0,BNX+G1/2.0,T+TDEL1/2.0)
      F3=TDEL1*TKNT(BNX+G2/2.0,T+TDEL1/2.0)
      G3=TDEL1*DNTC(RMY+F2/2.0,BNX+G2/2.0,T+TDEL1/2.0)
      F4=TDEL1*TKNT(BNX+G3,T+TDEL1)
      G4=TDEL1*DNTC(RMY+F3,BNX+G3,T+TDEL1)
  108 RMY=RMY+(F1+2.0*F2+2.0*F3+F4)/6.0
      BNX=BNX+(G1+2.0*G2+2.0*G3+G4)/6.0
      RMWB=RMWB-RED+RMY
      GO TO 113
  112 X1=X2
      GO TO 117
  113 X1=FMWB
  117 IF(X1)109,109,110
  109 X1=0.0
      GO TO 120
  110 IF (BNX)111,111,120
  111 BNX=0.0
  120 XR=X1
      YR=BNX+2.0
      IF(XR)10,10,11
   11 IF (BNX) 12,12,13
   10 RAMN=0.0
      GO TO 116
   12 RAMN=FR/2.0
      GO TO 116
   13 FR=XR
      FB=YR
C
C     THE AMBUSHED-AMBUSHER FORCE RATIO.
C
      RAMN=FR/FB
  116 WRITE(6,7)T,YR,XR,RAMN
    7 FORMAT(/,28X,F6.2,8X,F5.3,14X,F7.3,25X,F6.3)
      T=T+TDEL1
      IF(XR)115,115,114
  114 IF (BNX) 115,115,104
  115 RETURN
      END
```

```
      SUBROUTINE MKUTTA (RMWA,BN1A,XA,YA)


      COMMON/COM1/TDEL1,TMAX,MRED,RED,PBAR
      T=0.0
      X3=RMWA
C
C
C     TWO AMBUSHERS WHO CONTROL THE CLAYMORES ARE NOT IN-
C     THE RANGE OF RIFLES
      BNX=BN1A-2
C     THE NUMBER OF THE AMBUSHED FORCE REDUCED BY RMW*P  RESULTED FROM
C     THECLAYMORES FIRE.
C
      RMWA=RMWA-RMWA*PBAR
      RMY=RMWA
C
C     THE RUNGE-KUTTA METHOD BEGINS.
C
   17 IF (T-0.0) 1,1,3
    3 IF (T-TMAX)4,5,5
    5 IF (RMWA-BN1A) 4,4,7
    4 F1=TDEL1*TKNT(BNX,T)
      G1=TDEL1*DNT(RMY,BNX,T)
      F2=TDEL1*TKNT(BNX+G1/2.0,T+TDEL1/2.0)
      G2=TDEL1*DNT(RMY+F1/2.0,BNX+G1/2.0,T+TDEL1/2.0)
      F3=TDEL1*TKNT(BNX+G2/2.0,T+TDEL1/2.0)
      G3=TDEL1*DNT(RMY+F2/2.0,BNX+G2/2.0,T+TDEL1/2.0)
      F4=TDEL1*TKNT(BNX+G3,T+TDEL1)
      G4=TDEL1*DNT(RMY+F3,BNX+G3,T+TDEL1)
      GO TO 8
    7 F1=TDEL1*TKNT(BNX,T)
      G1=TDEL1*DNTC(RMY,BN1A,T)
      F2=TDEL1*TKNT(BNX+G1/2.0,T+TDEL1/2.0)
      G2=TDEL1*DNTC(RMY+F1/2.0,BNX+G1/2.0,T+TDEL1/2.0)
      F3=TDEL1*TKNT(BNX+G2/2.0,T+TDEL1/2.0)
      G3=TDEL1*DNTC(RMY+F2/2.0,BNX+G2/2.0,T+TDEL1/2.0)
      F4=TDEL1*TKNT(BNX+G3,T+TDEL1)
```

```
      G4=TDEL1*DNTC(RMY+F3,BNX+G3,T+TDEL1)
    8 RMY=RMY+(F1+2.0*F2+2.0*F3+F4)/6.0
      BNX=BNX+(G1+2.0*G2+2.0*G3+G4)/6.0
      GO TO 13
    1 XA=X3
      GO TO 18
   13 IF(RMY)9,9,10
    9 RMY=0.0
      GO TO 12
   10 IF (BNX) 11,11,12
   11 BNX=0.0
   12 XA=RMY
   18 YA=BNX+2.0
C
C     THE AMBUSHED-AMBUSHER FORCE RATIO.
C
      AMNW=XA/YA
      WRITE(6,14)T,YA,XA,AMNW
   14 FORMAT(/,28X,F6.2,8X,F5.3,14X,F7.3,25X,F6.3)
      T=T+TDEL1
      IF(XA)15,15,16
   16 IF (BNX) 15,15,17
   15 RETURN
      END

      FUNCTION TKNT(BNXK,T1)

      COMMON/COM2/APHK,ZETA,DELTA
      TKNT=-BNXK*APHK/(1.0-EXP(-ZETA*T1-DELTA))
      RETURN
      END

      FUNCTION DNT(RMYD,BNXK,T2)

      COMMON/COM3/AK1,AK2,GAMMA,ROAD
      EX=EXP(-GAMMA*T2)
      DNT=-(AK2*(1.0-EX)+AK1*BNXK*EX)*RMYD
      RETURN
      END

      FUNCTION DNTC (RMYD,BNXK2,T3)

      COMMON/COM3/AK1,AK2,GAMMA,ROAD/COM4/CN
      EX=EXP(-GAMMA*T3)
      DNTC=-(AK2*(1.0-EX)+AK1*BNXK2*EX)*RMYD-CN*(RMYD/BNXK2-1.0)**2
      RETURN
      END
//GO.SYSIN DD *
```

APPENDIX B

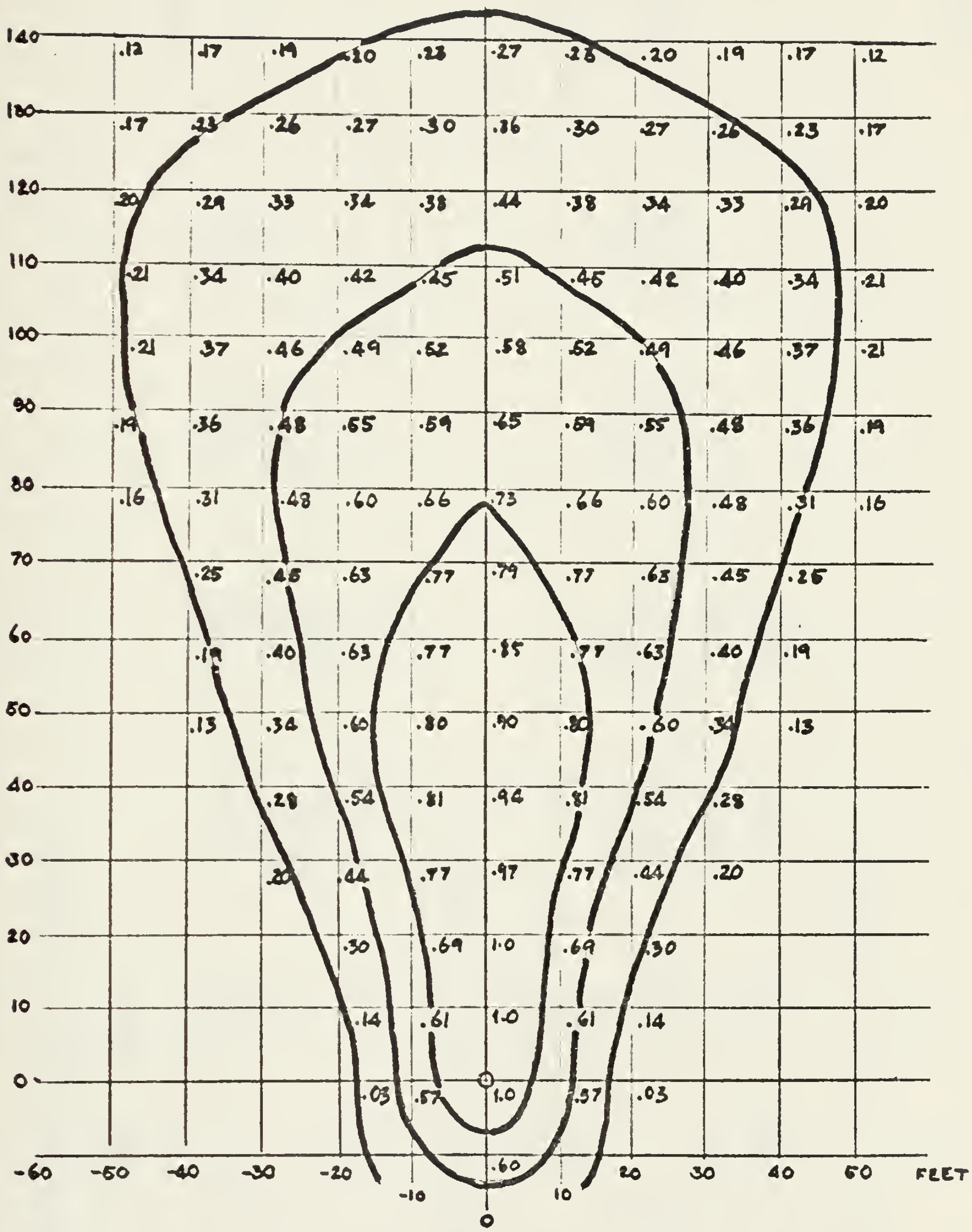

Figure 11 Lethality Pattern of a T48 Claymore

Probability of incapacitation as a function of the location of a person relative to a detonated T48 claymore under simulated combat conditions. The claymore is to be considered located at (0,0) and aimed straight up the page.
Source : "Claymore Employment Techniques Experiment", Memorandum Report, USACDEC, Ft.Ord.Calif, 27 May 1958.

APPENDIX C: COMPUTER DATA INPUTS USED IN THIS STUDY

```
   DATA INPUT FOR TYPE 1 AMBUSH

     RMW     BN1   ROAD
     30.0    7.0   25.0                                               02250
 TMAX      RB          AT      DELTA     ZETA     GAMMA    ZIGMA
3.C0000  20.0         1.68      0.4     0.572     0.516    2.952      02260
   AK1       AK2      CN       TDEL1     PHK
0.0012      07560    1.0        0.5     0.8

   DATA INPUT FOR TYPE 2 AMBUSH

     RMW     BN1   ROAD
     30.0    7.0   25.0                                               02280
 TMAX      RB          AT      DELTA     ZETA     GAMMA    ZIGMA
3.0      20.0         1.68      0.4     0.572     0.516    2.952      02290
   AK1       AK2      CN       TDEL1     PHK
0.0012      07560    1.0        0.5     0.8

   DATA INPUT FOR TYPE 3 AMBUSH

     RMW     BN1   ROAD
     30.0    7.0   25.0                                               02310
 TMAX      RB          AT      DELTA     ZETA     GAMMA    ZIGMA
3.0      20.0         1.68      0.4     0.572     0.516    2.952      02320
```

```
   AK1       AK2       CN        TDEL1       PHK
0.0008    0.07560     1.0         0.5        0.8

   DATA INPUT FOR TYPE 4 AMBUSH

     RMW       BN1     ROAD
     30.0      7.0     25.0                                                      02340
 TMAX        RB          AT       DELTA       ZETA       GAMMA      ZIGMA
3.0        20.0         1.68       0.4        0.572      0.516      2.952        02350
   AK1       AK2       CN        TDEL1       PHK
0.00132   0.0756      1.0         0.5        0.8

   DATA INPUT FOR TYPE 5 AMBUSH

     RMW       BN1     ROAD
     30.0      7.0     25.0                                                      02370
 TMAX        RB          AT       DELTA       ZETA       GAMMA      ZIGMA
3.0        20.0         1.68       0.4        0.572      0.516      2.952        02380
   AK1       AK2       CN        TDEL1       PHK
0.00096   0.0756      1.0         0.5        0.8
```

APPENDIX D: TABULAR NUMBERICAL RESULTS OF THE VARIOUS AMBUSH DEPLOYMENT SCHEMES

AMBUSH TYPE 1

INITIAL AMBUSHER FORCE............= 7 UNITS
INITIAL AMBUSHED FORCE............= 30 UNITS
THE WIDTH OF THE ROAD = 25 FT.

TIME(MIN)	AMBUSHER FORCE	AMBUSHED FORCE	AMBUSHED-AMBUSHER FORCE RATIO
0.0	7.000	30.000	4.286
0.50	6.900	12.288	1.781
1.00	6.756	10.518	1.557
1.50	6.578	8.995	1.367
2.00	6.374	7.645	1.199
2.50	6.169	5.738	0.930
3.00	6.008	2.022	0.337
3.50	5.959	0.0	0.0

AMBUSH TYPE 2

INITIAL AMBUSHER FORCE............= 7 UNITS

INITIAL AMBUSHED FORCE............= 30 UNITS

THE WIDTH OF THE ROAD = 25 FT.

TIME(MIN)	AMBUSHER FORCE	AMBUSHED FORCE	AMBUSHED-AMBUSHER FORCE RATIO
0.0	7.000	30.000	4.286
0.50	6.900	12.288	1.781
1.00	6.756	10.518	1.557
1.50	6.578	8.995	1.367
2.00	6.374	7.645	1.199
2.50	6.169	5.738	0.930
3.00	6.008	2.022	0.337
3.50	5.959	0.0	0.0

AMBUSH TYPE 3

INITIAL AMBUSHER FORCE............= 7 UNITS
INITIAL AMBUSHED FORCE............= 30 UNITS
THE WIDTH OF THE ROAD = 25 FT.

TIME(MIN)	AMBUSHER FORCE	AMBUSHED FORCE	AMBUSHED-AMBUSHER FORCE RATIO
0.0	7.000	30.000	4.286
0.50	6.822	12.302	1.803
1.00	6.607	10.573	1.600
1.50	6.380	9.106	1.427
2.00	6.157	7.819	1.270
2.50	5.947	6.663	1.120
3.00	5.605	5.623	1.003
3.50	5.344	4.697	0.879
4.00	5.154	3.850	0.747
4.50	5.012	3.061	0.611
5.00	4.885	2.316	0.474
5.50	4.733	1.612	0.341
6.00	4.518	0.957	0.212
6.50	4.201	0.371	0.088
7.00	3.730	0.0	0.0

AMBUSH TYPE 4

INITIAL AMBUSHER FORCE............= 7 UNITS

INITIAL AMBUSHED FORCE............= 30 UNITS

THE WIDTH OF THE ROAD = 25 FT.

TIME(MIN)	AMBUSHER FORCE	AMBUSHED FORCE	AMBUSHED-AMBUSHER FORCE RATIO
0.0	7.000	30.000	4.286
0.50	6.811	12.305	1.807
1.00	6.588	10.581	1.606
1.50	6.356	9.121	1.435
2.00	6.130	7.842	1.279
2.50	5.917	6.694	1.131
3.00	5.559	5.665	1.019
3.50	5.280	4.752	0.900
4.00	5.075	3.924	0.773
4.50	4.924	3.156	0.641
5.00	4.798	2.433	0.507
5.50	4.660	1.749	0.375
6.00	4.471	1.111	0.248
6.50	4.194	0.531	0.127
7.00	3.784	0.037	0.010
7.50	3.160	0.0	0.0

AMBUSH TYPE 5

INITIAL AMBUSHER FORCE............= 7 UNITS
INITIAL AMBUSHED FORCE............= 30 UNITS
THE WIDTH OF THE ROAD = 25 FT.

TIME(MIN)	AMBUSHER FORCE	AMBUSHED FORCE	AMBUSHED-AMBUSHER FORCE RATIO
0.0	7.000	30.000	4.286
0.50	6.819	12.303	1.804
1.00	6.602	10.576	1.602
1.50	6.373	9.111	1.430
2.00	6.149	7.826	1.273
2.50	5.938	6.672	1.124
3.00	5.591	5.636	1.008
3.50	5.325	4.714	0.885
4.00	5.130	3.873	0.755
4.50	4.986	3.090	0.620
5.00	4.859	2.351	0.484
5.50	4.712	1.653	0.351
6.00	4.505	1.003	0.223
6.50	4.200	0.418	0.100
7.00	3.748	0.0	0.0

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